AS Level Physics

Chapter 5 – Mechanics

5.2.2 Kinematics

Worked Examples

Question 1

a) Define acceleration.
b) State the **two** factors that affect the acceleration of an object.
c) Fig. 4.1 shows the variation of velocity *v* with time *t* for a small rocket.

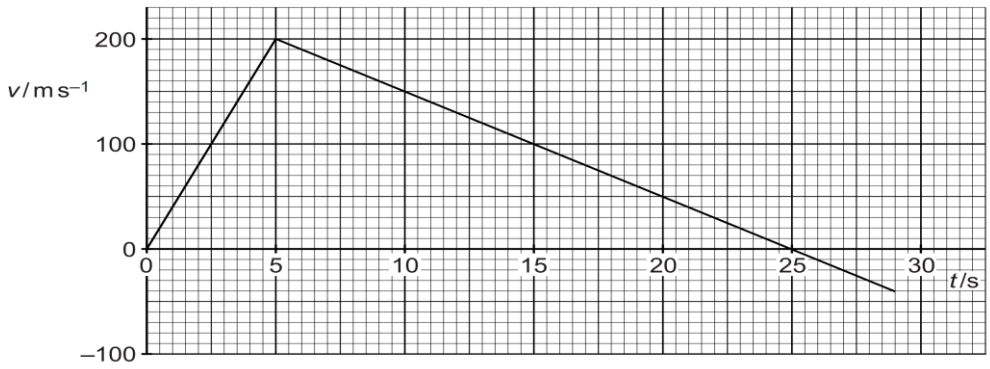


Fig. 4.1

The rocket is initially at rest and is fired vertically upwards from the ground. All the rocket fuel is burnt after a time of 5.0 s when the rocket has a vertical velocity of 200 m/s. Assume that air resistance has a negligible effect on the motion of the rocket.

i) Without doing any calculations, describe the motion of the rocket
1) from t = 0 to t = 5.0 s
2) from t = 0.5 s to t = 25 s.
ii) Calculate the maximum height reached by the rocket.

a) Define acceleration
Acceleration = rate of change of velocity = change in velocity/time

b) Two factors that affect acceleration
Acceleration is affected by the mass and force.

ci) 1: Describe motion
From t = 0 to t = 5.0s: shows a positive gradient. This means that the velocity is increasing therefore the rocket is accelerating.

ci) 2: Describe motion
From t= 0.5 s to t = 25 s: shows a negative gradient. This means that the velocity is decreasing therefore the rocket is decelerating. The line also crosses the x-axis at t = 25s, this means that the rocket has reached its maximum height or has stopped and is now coming back down.

cii) Calculate the maximum height reached by the rocket

$$height = area\ under\ graph\ from\ 0\ to\ 25\ s$$

$$height = \frac{1}{2} \times 25 \times 200$$

$$height = \mathbf{2500\ m}$$

The area under the graph can be represented as a triangle. The area of a triangle can be calculated using:
Area of a triangle = ½ x base x height

The area under the graph represents displacement and as the rocket is going vertically upwards this means the displacement represents the maximum height.

Question 2

a) Define acceleration.
b) A super-tanker cruising at an initial velocity of 6.0 m/s takes 40 minutes (2400 s) to come to a stop. The super-tanker has a constant deceleration.
i) Calculate the magnitude of the deceleration.
ii) Calculate the distance travelled in the 40 minutes it takes the tanker to stop.
iii) On Fig. 1.1, sketch a graph to show the variation of distance x travelled by the super tanker with time t as it decelerates to a stop.

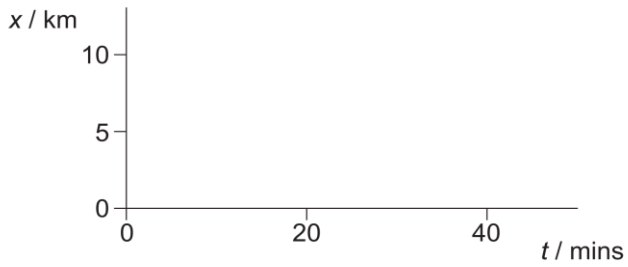


Fig. 1.1

a) Define acceleration

Acceleration = rate of change of velocity = change in velocity/time

bi) Calculate the magnitude of the deceleration

$$a = \frac{v - u}{t}$$

Where: v = final velocity, u = initial velocity, t = time

Remember the final velocity is zero because it tells us in the question that the super-tanker comes to a stop.

$$a = \frac{0\ m\ s^{-1} - 6.0\ m\ s^{-1}}{2400\ s} = \mathbf{-2.5\ \times 10^{-3}\ ms^{-2}}$$

bii) Distance travelled

$$Average\ speed = \frac{distance}{time}$$

$$distance = average\ speed \times time$$

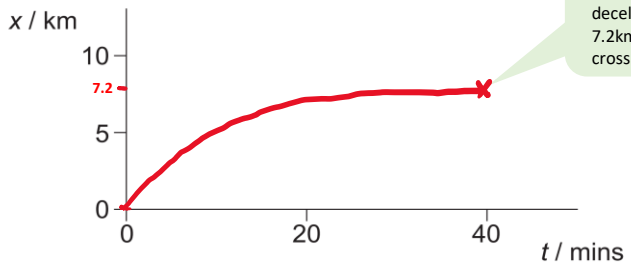
$$Average\ speed = \frac{6.0\ ms^{-1} + 0\ ms^{-1}}{2} = 3\ ms^{-1}$$

$$Distance = 3.0\ ms^{-1} \times 2400\ s$$

$$\boldsymbol{Distance = 7200\ m}$$

Average speed can be calculated by adding the final speed and initial speed and then dividing it by two (in other words you are finding the mean). There are other ways to figure this question out but we will come to those in later packs.

biii) Sketch



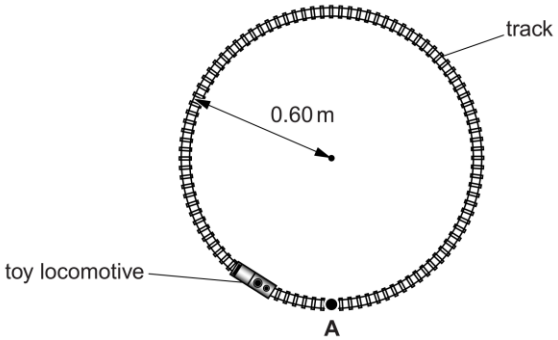
This graph shows that the object is slowing down (or decelerating). We know that while decelerating the tanker travels 7200m (or 7.2km) in 40 minutes. So the curve should cross (40,7.2)

Fig. 1.1

Question 3

a) Speed is a scalar quantity and velocity is a vector quantity. State one difference and one similarity between speed and velocity.

b) Fig. 2.1 shows a toy locomotive on a circular track.



Locomotive just means a train.

Fig. 2.1

The locomotive travels at constant speed round the track in a clockwise direction. It takes 12 s to travel completely round the track. At time t = 0, the locomotive is at point A.

i) Calculate the speed of the locomotive

ii) Calculate the magnitude of the displacement s of the locomotive from point A after it has travelled one quarter of the way round the track.

iii) Explain why the average velocity of the locomotive is zero after a time of 12 s.

iv) Explain why the velocity of the locomotive changes even though its speed is constant.

a) Difference and similarity between speed and velocity

Difference: Velocity needs to have a direction whereas the speed doesn't.

Similarity: Velocity and speed both have a magnitude and both have the same units (m/s or ms^{-1}).

bi) Calculate the speed

$$Speed(ms^{-1}) = \frac{distance\ (m)}{time\ (s)}$$

$$Distance = perimeter\ of\ the\ circle = 2\pi r = 2 \times \pi \times (0.60\ m) = 3.77\ m$$

$$Speed = \frac{3.77\ m}{12\ s}$$

$$\boldsymbol{Speed = 0.31\ ms^{-1}}$$

bii) Calculate the displacement of the locomotive after it has travelled ¼ of the way round the track

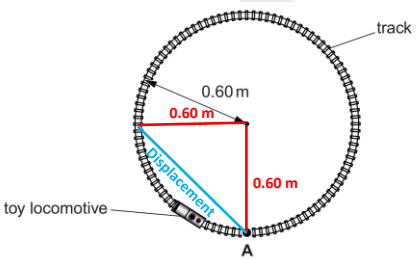


Fig. 2.1

The red lines represent a quarter of the distance round the track. The displacement is the blue line joining the red lines together. Notice this makes a right-angled triangle. Therefore using Pythagoras theorem you can work out the displacement:

$$Pythagoras\ theorem: c^2 = a^2 + b^2$$

$$displacement^2 = 0.6^2 + 0.6^2$$

$$displacement = \sqrt{0.6^2 + 0.6^2}$$

$$\boldsymbol{displacement = 0.85\ m}$$

Question 3

a) Speed is a scalar quantity and velocity is a vector quantity. State one difference and one similarity between speed and velocity.

b) Fig. 2.1 shows a toy locomotive on a circular track.

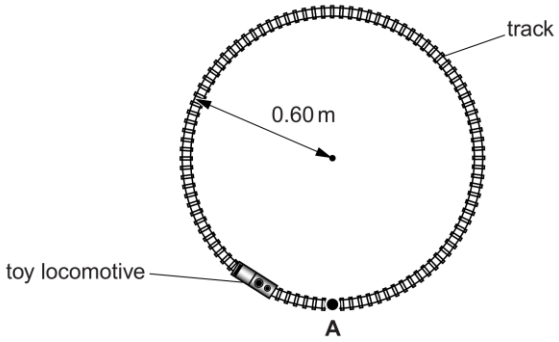


Fig. 2.1

The locomotive travels at constant speed round the track in a clockwise direction. It takes 12 s to travel completely round the track. At time t = 0, the locomotive is at point A.

i) Calculate the speed of the locomotive

ii) Calculate the magnitude of the displacement s of the locomotive from point A after it has travelled one quarter of the way round the track.

iii) Explain why the average velocity of the locomotive is zero after a time of 12 s.

iv) Explain why the velocity of the locomotive changes even though its speed is constant.

a) <u>Explain why the average velocity is zero</u>

Velocity depends on displacement and time. Displacement is the distance moved relative from the starting position (A). So, after 12 seconds the locomotive comes back to its starting position (A), so the displacement is zero and if the displacement is zero velocity is also zero so:

Average velocity of the locomotive after 12 s is zero because the change in displacement is zero.

<u>bii) Explain why the velocity of the locomotive changes even though the speed is constant</u>

You need to remember that speed is a scalar quantity and only needs a magnitude and that magnitude can stay constant.

Velocity is a vector quantity. This means that velocity needs to have a magnitude as well as a direction. So even though the magnitude is the same, the direction isn't (because the locomotive is moving in a circle and so the direction is constantly changing) and therefore the velocity is constantly changing.

So, the velocity changes even though the speed is the same because the locomotive keeps changing direction.

Please see the ‘5.2.1 Kinematics Notes’ for revision notes.

For revision notes, tutorials, worked examples and more help visit www.tutorpacks.co.uk.